

# Transport in Plants

In flowering plant subs transported

- Water
- mineral nutrients
- org. nutrients
- Plant growth reg. (Hormones)

Small distances → Subs move by

- diffusion
- cytoplasmic streaming

→ Active.

Long dist → vascular system supplemented by active transport.

xylem  
phloem

## Translocation

Important aspect in plants → dir of transport.

XYLEM → in rooted plants, water & minerals → essentially Unidirectional from roots to stem.

PHLOEM → Bidirectional for Organic & mineral nutrients.

Org. compounds synthesised in leaves → exported to parts of plants including Storage organs.

Mineral nutrients taken up by roots trans. → to stem, leaves & growing region

Any plant part undergoes senescence → nutrients withdrawn from & moved to growing parts. later re-exported.

Hormones (PGRs) & other chem. stimuli → in small amounts → sometimes sharply polarised or unidirectional from where synthesised to other parts.

Hence, in flowering plants → complex traffic of (yet orderly) comp.

## Means of Transport

### ① Diffusion <sup>NOT highly selective.</sup>

- movement - passive
- from one part of cell to other / cell to cell (short dist)
- No energy expenditure.
- molecules move in random fashion
- high conc. to lower conc.
- SLOW Process.
- not dependent on living system
- Diff in solids rather than of solids more likely.
- Obvious in gases & liquids.
- imp in plants because only means of gas movement in plant body.

### ② Fac. Diffusion.

- For subs with hydrophilic nature
- mem. protein provides sites at which they cross the mem.
- They do not set a conc. gradient, a conc gradient must be already present even if facilitated by protein → facilitated diff.
- Special proteins

W/O ATP expendi.

- High to low (passive)
- Protein transporters

① Saturation (Transport rate max when all protein are used)

② Specific.

③ sensitive to inhibitors

Heard with protein chains.

④ some open, others can be controlled

⑤ Some large → allows variety of molecules to pass.

Soluble in lipid → diffuse faster.

Major constituent of membrane

PORINS → LARGE PORES → in outer membranes of

Plants, mitochondria & some bacteria. allowing molecules UP TO size of small proteins to pass.

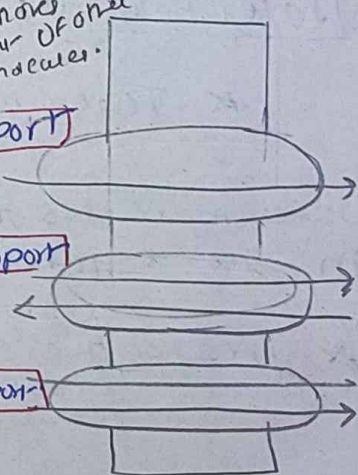
- (carrier protein)
- Some transport protein rotate & releases molecules inside the cell eg. water channels
- made of 8 diff types of aquaporins

molecule moves independent of other molecules.

Uniport

Antiport

Symport



Some carrier or transport proteins allow diffusion only if two types of molecules move together.



③ Active Transport → uses ATP to PUMP molecules against conc. gradient

• Caused out by → specific mem. proteins hence diff. proteins in memb. play a major role in both active & passive transport.

• Pumps → proteins using energy  
→ low conc to high (uphill)

• Protein Transporter → ① saturable ② selective specific (Like enzymes) ③ sensitive to inhibitors

like fac. diffusion → ④ under hormonal regulation (controlled)  
↓  
react w protein side chains.

## PLANT-WATER RELATIONS.

Water → essential for physiological activities  
• plays imp role in all living org.  
• provides medium in which MOST subs dissolve  
• protoplasm is water with diff molecules dissolved & several particles suspended.

• Watermelon → over 92% water of pts  
• Herbaceous plant → only 10-15% FRESH WT as dry matter.

• Distribution of water in plant varies → woody → relatively less water  
→ soft → mostly contain water.  
seed → has water (may appear dry)

Terrestrial plants → take up huge amt. of water → most lost to air thru evap. → Transpiration.  
from leaves

corn plant absorbs 3 l of water a day  
mushroom plant absorbs equal to its own wt in 5 hrs.

★ Because of high demand → Water is often limiting factor for plant growth & productivity in agricultural & natural enviro.

④ Water Potential:- concept fundamental to understanding water movement.

★ Two main components that determine  $\Psi_w$  → solute potential ( $\Psi_s$ )  
→ pressure potential ( $\Psi_p$ )

Water molecules possess K.E.  
in liq & gaseous form they are in random motion i.e. both → rapid & constant.

★ Greater the conc. of water in system, Greater is its K.E. → Water potential

↓ Hence. (A.R.)  
★ Pure water will have greatest water potential. → zero



\* if 2 systems containing water are in contact  $\rightarrow$  random movement of water molecules  $\xrightarrow{\text{results}}$  net movement of water from system with

$\Psi_w \rightarrow$  units.  
 $\downarrow$   
 Pressure  
 Pascals (Pa)

higher water potential to lower  $\Psi_w$   $\leftarrow$  i.e. high energy to low energy

\* By convention,  $\Psi_w$  Pure water at std. temp, not under any pressure

Zero.

\* If some solute  $\rightarrow$  dissolved in water  $\rightarrow$  soln has fewer free molecules  $\rightarrow$  (conc<sup>n</sup> of water) (free energy)  $\downarrow$

Hence (A.R)  
 $\downarrow$   
 all solns have a water potential lower than pure water (-ve)

The magnitude of this lowering due to dissolution of a solute

$\Psi_s$  (solute potential)  $\rightarrow$  always -ve.

\* more solute molecules  $\rightarrow$  lower (more negative)  $\rightarrow \Psi_s$ .

\* For solution  $\rightarrow$  at atm  $\rightarrow \Psi_w = \Psi_s$ .

\* if pressure  $>$  than atm pressure  $\rightarrow$  applied to pure water OR soln  $\rightarrow$  water potential increases

\* Pressure can build up in plant system  $\xrightarrow{\text{when}}$  water enters a plant cell due to diffusion leaving

pressure built up against wall  $\rightarrow$  cell turgid

this increases pressure potential.

\*  $\Psi_p \rightarrow$  usually +ve  
 though in plants  
 $\downarrow$   
 -ve potential or tension in water column of xylem plays major role in water transport up a stem.

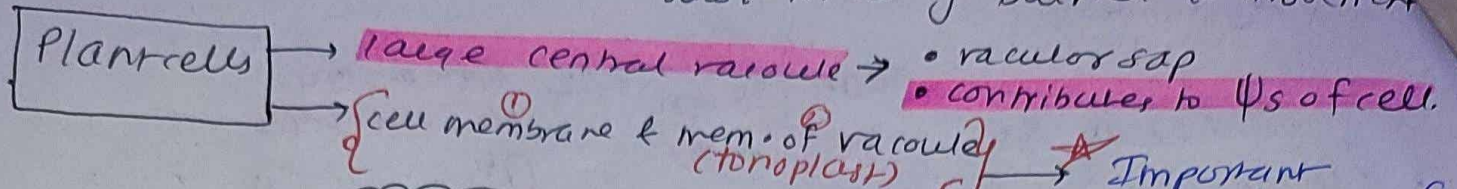
\*  $\Psi_w$  affected by  $\Psi_s$  &  $\Psi_p$

$$\Psi_w = \Psi_s + \Psi_p$$



# Osmosis:-

- Cell wall  $\rightarrow$  freely permeable to water
- subst. in sol<sup>n</sup> } hence NOT a Barrier to movement



**Osmosis**  $\rightarrow$  Important determinants of movements of molecules in or out of cell.

used to refer specifically diffusion of water

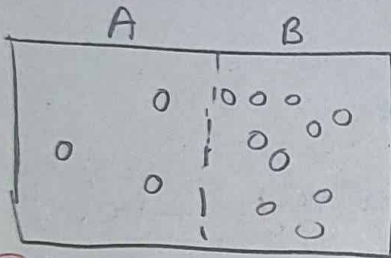
occurs spontaneously in response to driving force.

across differentially or selectively permeable membrane

> Net direction  
> rate of osmosis } depends on

- Pressure gradient ①
- Conc. gradient ②

\* Water will move from its region of higher chemical potential (conc.)  $\rightarrow$  lower chemical potential



both chambers should have nearly same water.

unit (eg  $g\ m^{-3}$ )

① lower  $\Psi_w \rightarrow B$  ② lower  $\Psi_s \rightarrow B$  ③ dir<sup>n</sup> of osmosis  $\rightarrow A$  to  $B$

④ if one chamber has  $\Psi$  of  $-2000\ kPa$  & other  $-1000\ kPa$ , which has highest  $\Psi \rightarrow -1000\ kPa$ .

⑤ dir<sup>n</sup> of movement of water when two sol<sup>n</sup> with  $\Psi_w = 0.2\ MPa$  &  $\Psi_w = 0.1$  are separated by SPM?  $\rightarrow 0.2\ MPa$  to  $0.1\ MPa$ .

\* External Pressure can be applied from upper part of funnel such that no water diffuses into funnel thru membrane.

required to prevent water from diffusing  $\rightarrow$  Osmotic pressure  $\rightarrow$  function of solute conc.

\* more solute conc<sup>n</sup>  $\rightarrow$   $\uparrow$  pressure required to prevent water from diffusing.

\* Numerically,  $O_s\ Pressure \equiv O_s\ Potential \rightarrow$  But sign is opposite.

\* Osmotic pressure  $\rightarrow$  positive pressure applied

\* Osmotic potential  $\rightarrow$  negative.



## Plasmolysis:- (Reversible process).

Behaviour of plant cells (tissues) with regard to water movement depends on surrounding solution.

- External solution
- a) balances osm. pressure of cytoplasm → isotonic.
  - b) more dilute than cytoplasm → hypotonic → cells swell
  - c) more concentrated → hypertonic → cells shrink

Plasmolysis → occurs

- when water moves out of cell & cell membrane of plant cell shrinks away from cell wall
- when cell (or tissue) placed in a sol<sup>n</sup> is hypertonic (more solutes) to the protoplasm.

\* Water → first lost from CYTOPLASM then from VACUOLE.

\* Water when drawn out of cell → into extracellular fluid → cause protoplast to shrink away from walls.

\* Hypertonic sol<sup>n</sup> → occupies space b/w cell wall & shrunken protoplast

Plasmolysed cell.

\* isotonic → no net flow of water → water flows into cell & out of cell are in eqbm → Flaccid cells.

\* hypotonic → water diffuses into cytoplasm

higher  $\psi_w$  or dilute as compared to cytoplasm

pressure against wall

Turgor Pressure.

responsible for enlargement & extension growth of cell.

• Because of rigidity of cell wall → cell doesn't rupture.

A.R.

\* Pressure exerted by protoplasts due to entry of water against rigid wall → pressure potential  $\psi_p$

•  $\psi_p$  of flaccid cell → 0

Imbibition :- special type of diffusion when water is absorbed by solids & colloids causing them to increase Volume.

examples.

- absorption of water by seeds & dry wood.
- pressure produced by swelling of wood → used by prehistoric man to split rocks & boulders.
- seedlings emerge out due to imbibition pressure.

• imbibition also → diffusion since → water movement along conc. gradient

• Water potential gradient b/w absorbent & liquid imbibed

①

essential for imbibition!

• Affinity b/w absorbent & liquid also → pre requisite.

②



# Long Dist. Transport:-

- ★ Diffusion → slow process.
- accounts for short-dist. movement

eg. Diffusion of a molecule across typical plant (50nm)

Time: 2-5s.

- ★ Sometimes, site of production or absorption → too far →

diffusion active transport } wouldn't suffice.

- ★ Special long dist. transport systems → necessary → move subs. across long dist → At much faster rate.

- ★ Water } moved by a mass and bulk flow
- minerals }
- food }

movement of subs in bulk or en masse from one point to other

as a result of A.R. Pressure difference. concentration

unlike diffusion where subs. move independently depending on their conc. grad.

can be achieved through { subs. in sol<sup>n</sup> or suspension are swept along at same pace → as in flowing river. }  
 +ve hydrostatic pressure gradient (eg. garden hose)  
 -ve - - - - - (eg. suction through straw)

- ★ Bulk movement of subs. through → conducting vascular tissues → of plants → Translocation

- Higher plants → xylem → translocation of water } from roots to aerial parts.
- phloem → translocates } org. solutes } mainly from leaves to other parts of plants.
- } inorg. solutes }
- } org. nitrogen }
- } inorg. nitrogen }

## ★ How do Plants Absorb Water?

Responsibility of absorption of water & minerals

more specifically → Function of Root Hairs

- present in millions at tips of roots
- thin-walled
- slender extensions of root-epidermal cells
- greatly inc. surface area for absorption.
- water absorbed along with mineral solutes → purely by diffusion!

makes deeper into root layers in two distinct pathways

→ apoplast

→ symplast.

APOPLAST → system of adjacent cells continuous except Caspary strip of endodermis

SYMPLAST → system of interconnected protoplasts.

- movement of water exclusively through → intercellular spaces & walls of cells.
- doesn't involve → crossing cell membrane.
- dependent on gradient.
- no barrier to (water movement) → thus mass flow.
- As water evaporates into intercellular spaces of atm. → tension develop in continuous stream → hence mass flow occurs due to adhesive & cohesive prop.

AR

- neighbouring cells connected through → cytoplasmic strands
- plasmodesmata. ← extend through
- water travels thru cells (cytoplasm) → relative slower
- movement → down potential gradient
- aided by cytoplasmic streaming
- eg. Hydrilla leaf → movement of chloroplasts due to cyto. streaming is visible.



Most water flows via APOPLAST

since

Cortical cells loosely packed.

A.R.

hence offer no resistance to water movement

inner boundary of cortex → endodermis

Water molecules unable to penetrate the layer

directed to water regions that are not suberised into cells through the membrane

Once inside xylem → water free to move b/w cells and through them.

in young roots → water enters directly into xylem and/or tracheids → nonliving conduits → apoplast.

Some plants have additional structures → help in water & mineral absorption

**Mycorrhiza** → symbiotic association of fungus with root system

fungus provides → mineral water to roots  
sugar & N-containing compounds to mycorrhizae.

Some plants → obligate association → with mycorrhiza → Pinus seeds cannot germinate & establish w/o mycorrhiza.

## Water movement up a Plant :-

### Root pressure

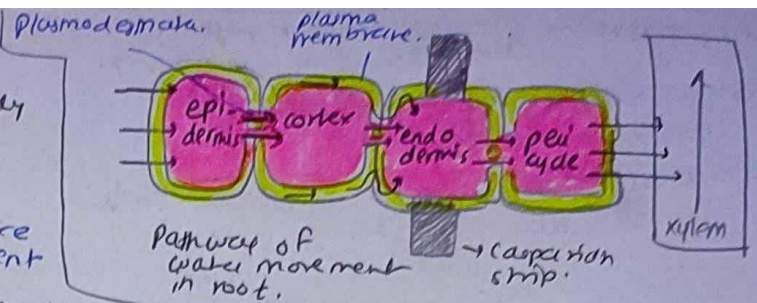
ions from soil are actively transported into vac. bundles → water follows (its potential gradient) → increases pressure inside xylem.  
+ve → Root Pressure  
pushes up water upto small heights.

seen in stem (cut) on a day.  
if rubber tube fixed to cut stem → exudation can be measured. also determine composition of exudates.

Effects → night early morning → evap is low → excess water collects in form of droplets around special openings of veins near tip of grass blades & leaves of herbaceous plants

### Guttation

such water loss in liquid phase



impermeable to water → because of band of suberised material CASPARIAN STRIP.

Water then moves through symplast again crosses membrane reach xylem

movement of water thru root layers ultimately symplastic in endodermis. only way water & other solutes can enter xylem.

Fungal filaments form network around young root or penetrate the root cells.  
Hyphae → large surface area → absorb mineral ions & water from much larger volume that root cannot do.

### Transpiration pull → most acceptable model

Upward flow of water through xylem can achieve fairly high rates upto 15 metres per hour

Water is mainly "pulled" through plant → driving force → Transpiration from leaves.

\* Cohesion-tension: transport pull model \*

Water → transient in plants less than 1% water reaching leaves → used in photosynthesis & plant growth → most lost through stomata → water loss

A study water loss from a leaf using → cobalt chloride paper → turns color on absorbing water.

### Transpiration



\* Root pressure → provides modest push in overall water transport  
 ↓  
 do not play major role in water movement up tall trees.

\* Greatest contribution → reestablish continuous chains of water molecules in xylem

↓  
 which break under enormous tensions  
 created by transpiration.

\* Root pressure → doesn't account for majority of water transport  
 most plant meet their needs by transpiration pull.

Transpiration:- evaporative loss of water by plants.

Occurs mainly through Stomata (sing. stoma)  
 exchange of oxygen & CO<sub>2</sub> also occurs thru this  
 open in day, close during night time.

Stomata → immediate cause of opening or closing → change in turgidity of guard cells

opening also aided due to orientation of cellulose microfibrils in cell walls of guard cells  
 oriented radially rather than longitudinally

inner wall → towards pore or stomatal aperture  
 thick & elastic  
 turgidity ↑↑ within two guard cells flanking each stomatal pore → thin outer walls bulge out

inner walls → crescent shape  
 turgidity ↓ due to water loss (or water stress)  
 inner walls regain original shape.

guard cell become flaccid & stoma closes.

\* Lower surface of dorsiventral (often dicotyledonous) has greater number of stomata

\* isobilateral (monocotyledonous) has equal on both surfaces

\* Transpiration affected by external factors:  
 • temperature  
 • light  
 • humidity  
 • windspeed.

plant factors →  
 • distribution of stomata  
 • % of open stomata  
 • water status of plant  
 • canopy structure.

Stomatal movement is not affected by O<sub>2</sub> conc. but by CO<sub>2</sub> conc (Pg-2018)

\* Transpiration driven

Ascent of Sap

depends on physical prop. of water.  
 • cohesion: mutual attr'n b/w water molecules  
 • adhesion: attr'n of water molecules to pit surface (sur. of tracheary elements)  
 • surface tension

These properties give water ① high tensile strength → ability to resist pulling force

② high Capillarity → ability to rise in thin tubes

aided by small diameter of tracheary elements

\* photosynthesis → requires water → xylem supplies

\* What force does plant use when parenchyma cell requires water?

Water evaporates thru stomata → thin film of water over cells is continuous → pulling of water molecule by molecule into leaf from xylem.



Because  $\rightarrow$  lower conc. of water vapour in atmosphere ~~as~~  
 A.R.  $\downarrow$  as compared to substomatal cavity & intercellular spaces  $\rightarrow$  water diffuses into surrounding air.

This creates "pull"

\* Measurements reveal  $\rightarrow$

force generated by transpiration  $\rightarrow$  creates sufficient pressure  $\rightarrow$  lift xylem  $\rightarrow$  130m high

lift xylem  $\rightarrow$  130m high  
 sized column of water over

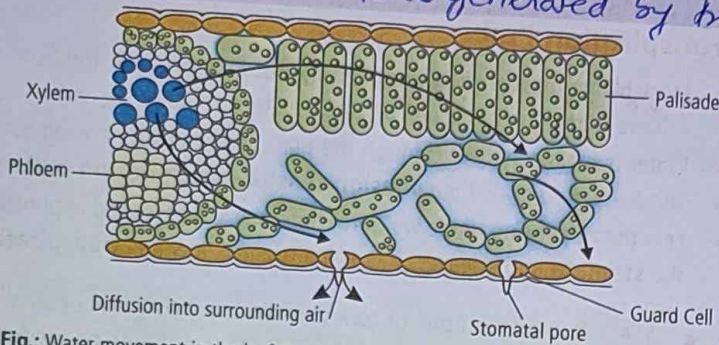


Fig.: Water movement in the leaf. Evaporation from the leaf sets up a pressure gradient between the outside air and the air spaces of the leaf. The gradient is transmitted into the photosynthetic cells and on the water-filled xylem in the leaf vein.

## Transpiration & Photosynthesis :- a compromise.

more than one purpose

creates trans. pull for absorption & transport of plants

supplies water for photosynthesis

transports mineral from soil to all parts of plant

not absorb

cools leaf surface to 10-15 degrees by evaporative cooling.

maintains shape & structure of plants by keeping cells turgid.

\* Actively photosynthesising plant has an insatiable need for water.

Photosynthesis is limited by available water which can be

swiftly depleted by transpiration

\* Humidity of rain forests  $\rightarrow$  largely due to this vast cycling of water from root to leaf to atm & back to soil.

\* Evolution of  $C_4$  Photosynthesis one of the strategies for maximising availability of  $CO_2$   $\rightarrow$  while minimising water loss.

\*  $C_4$  plants  $\rightarrow$  twice as efficient as  $C_3$  plants in

in fixing carbon dioxide (making sugar)

$\downarrow$   
 loses half as much as water as a  $C_3$  plant for same amt. of  $CO_2$  fixed.



# \* Uptake & Transport of mineral nutrients :-

Plants obtain C & most O<sub>2</sub> → from CO<sub>2</sub> → in atm.

remaining nutrition → from water & minerals → soil

## Uptake of Mineral ions

Water : passively (osmosis)

Minerals (most) : actively

Two factors account for this A.R.

• minerals present in soil → charged (ions) cannot move across cell membrane

• conc. of minerals in the soil is usually lower than conc. of minerals in root

Therefore, most minerals enter root by Active Abs<sup>n</sup> → into cytoplasm of epidermal cells.

Active uptake of ions partly → for water potential gradient → in roots therefore uptake of water

some ions also move into epidermal cell passively

Ions are absorbed from soil → passively (some) → actively (most)

Specific proteins → in membrane of root hair cells → actively pump ions from soil in cyto. of epidermis

Like all cells → Endodermal cells have transport proteins (embedded in plasma membrane) → let some solutes cross membrane → not others.

Control points

where plants adjust quantity of & types of solutes that reach xylem

NOTE: Root endodermis because of layer of suberin has ability to actively transport ions in ONE dir<sup>n</sup> only! A.R.

## Translocation of mineral ions

through transpiration stream (with water)

The chief sinks for mineral elements → growing regions

• apical & lateral meristems  
• young leaves  
• storage organs  
• developing flowers, fruits & seeds.

Unloading of mineral ions across at fine veins → diffusion & active uptake by these cells.

mineral ions frequently remobilised from older, senescing parts → export much of mineral content to younger leaves.

Before fall in deciduous plants → mineral are removed to other parts.

Elements readily mobilised → N, P, K, Mg  
not mobilised → Ca, S. (structural component)



## Phloem transport: Flow from source to sink.

\* Food  $\rightarrow$  primarily **Sucrose**  $\rightarrow$  transported by **Vascular tissue**  $\rightarrow$  **Phloem** (from source to sink).

\* **Source**  $\rightarrow$  part which synthesizes food i.e. **leaf**  
\* **Sink**  $\rightarrow$  part that needs food or stores food.

\* may be reversed depending on season or plant's needs.

\* sugar stored in roots  $\rightarrow$  mobilised to become source of food in **early spring** when  
need energy for **growth** & **development of photosynthesis app.**  
① **Buds**  $\xrightarrow{\text{as}}$  sink

\* Since  $\rightarrow$  source-sink relationship  $\rightarrow$  **Variable**  $\rightarrow$  direction of movement in phloem can be

upwards  $\swarrow$  downwards

\* **Xylem**  $\rightarrow$  always  $\rightarrow$  unidirectional  $\leftarrow$  contrast **phloem is bidirectional.**

$\downarrow$  hence

unlike 1-way flow of water in transpiration, food  $\xrightarrow{\text{in}}$  phloem sap  $\xrightarrow{\text{transported}}$  any req. so long as there is source of sugar & sink able to use, store or remove sugar.

\* Phloem sap  $\xrightarrow{\text{mainly}}$ 

- water
- sucrose

 but other sugars 

- hormones
- amino acids

 } also transported **translocated** through phloem

### Pressure Flow or Mass Flow Hypothesis.

$\rightarrow$  accepted mechanism used for translocation of sugars from source to sink.

$\rightarrow$  explaining translocation in phloem.

Glucose prepared at source (photosynthesis)

converted to **sucrose** (disaccharide)

**Loading**  $\leftarrow$ 

- hypertonic cond<sup>n</sup> in the phloem

 moved in the form of  $\uparrow$  into **companion cells**  
 $\downarrow$  then to living phloem sieve tube cells by **Active transport.**

Water in adjacent xylem moves into the phloem by **osmosis.**

Osmotic pressure  $\downarrow$  builds up  $\rightarrow$  phloem sap move to area of **lower pressure**

$\downarrow$  at sink  $\rightarrow$  Osm. pressure must be reduced

Again  $\rightarrow$  **Active transport**  $\rightarrow$  necessary for moving sucrose out of phloem sap and into the cells  $\rightarrow$  which will use sugar - converting it into energy, starch or cellulose.



\* As sugars removed  $\rightarrow$  osmotic pressure decreases  $\rightarrow$  water ~~then~~ moves out of phloem. (in xylem)

summarised:

\* movement of sugar in the phloem begins at

Source  $\rightarrow$  where sugars are loaded (actively transported) into sieve tube.

Loading of phloem sets up a water potential gradient that facilitates mass movement in the phloem.

\* Phloem tissue  $\rightarrow$  composed of sieve tube cells, form long column with holes in end walls  $\rightarrow$  sieve plates. Cytoplasmic strands pass through holes in sieve plates forming continuous filaments.

as hydrostatic pressure in sieve tube increases pressure flow begins & sap moves through phloem.

at sink incoming sugars  $\rightarrow$  actively transported out of phloem and removed as complex carbs.

The loss of solute produces  $\rightarrow$  high water potential in the phloem  $\rightarrow$  water passes out returning eventually to xylem.

Girdling  $\rightarrow$  experiment used to identify tissues through which food is transported (phloem)

On tree trunk  $\rightarrow$  a <sup>ring of</sup> bark upto phloem layer  $\rightarrow$  removed  $\rightarrow$  in absence of downward movement of food

\* This exp. <sup>shows</sup>  $\rightarrow$  phloem is the tissue responsible for translocation of food  
 • transport takes place in one dirn (i.e. towards roots)

portion of bark above ring on stem swollen after few weeks.

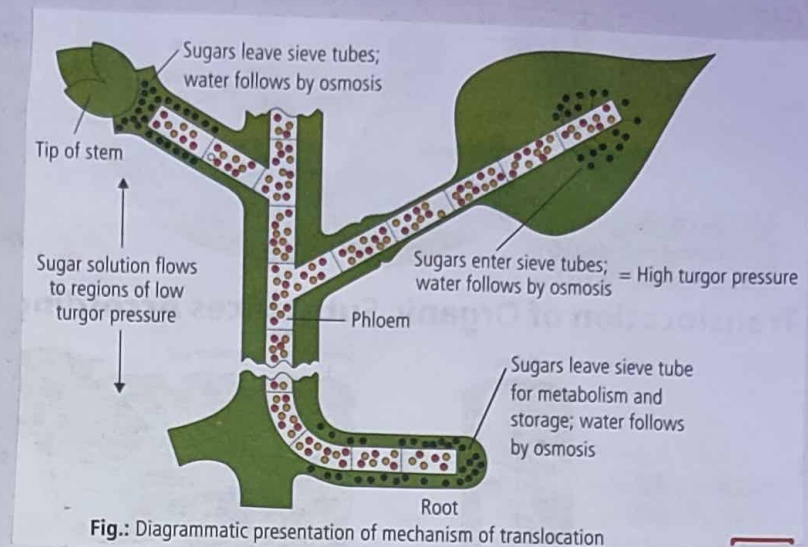


Fig.: Diagrammatic presentation of mechanism of translocation

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